OPEN-FILE REPORT 2000-010

SEISMIC HAZARD EVALUATION OF THE SAN JOSE EAST 7.5-MINUTE QUADRANGLE, SANTA CLARA COUNTY, CALIFORNIA

2000

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
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Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the San Jose East 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the San Jose East 7.5-Minute Quadrangle, Santa Clara County, California

By
Kevin B. Clahan, Elise Mattison, and Keith L. Knudsen

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the Seismic Hazard Zones identified by DMG. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997;also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the San Jose East 7.5-minute Quadrangle (scale 1:24,000). This section, Section 2 addressing earthquake-induced landslides, and Section 3 addressing potential ground shaking, form a report that is one of a series that summarizes production of similar hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet web page: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in northern California. During the 1989 Loma Prieta earthquake, significant damage to roads, utility pipelines, buildings, and other structures in the San Francisco Bay Area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions are widespread in the San Francisco Bay Area, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard, especially in areas marginal to the bay, including areas in the San Jose East Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys and floodplains. DMG's liquefaction hazard evaluation is based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from a variety of sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to freefaces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to evaluate the potential for ground failure at any given project site.

Information developed in this study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The San Jose East Quadrangle includes nearly 62 square miles of heavily urbanized terrain in Santa Clara County, California. The City of San Jose, including part of the downtown area in the northwestern corner, covers much of the quadrangle. On the north the map boundary bisects the community of East Foothills near Alum Rock. San Francisco Bay lies about 10 miles to the northwest and the Pacific Ocean is about 25 miles to the west.

Most of the western half of the quadrangle consists of an alluvial plain that is part of the Santa Clara Valley. This part of the Santa Clara Valley is drained by Coyote Creek, which flows diagonally across the entire quadrangle in the central part of the map area. South of Coyote Creek there are a few hills. West-facing slopes of the Diablo Range, called the San Jose Foothills in this area, rise above the valley in the eastern half of the quadrangle. The geologic structure of the Coast Ranges, which consist of northwest-trending folds and faults, controlled the development of the ridges and intervening valleys of the San Jose Foothills in the northeastern part of the quadrangle. To the south, the Silver Creek Hills (also called Yerba Buena Ridge) lie parallel to and west of the San Jose Foothills, and extend into the Santa Clara Valley. Evergreen Valley lies between the Silver Creek Hills and the San Jose Foothills and widens northward into the Santa Clara Valley. Thompson Creek flows through Evergreen Valley and into Silver Creek in Santa Clara Valley, then into Miguelita Creek, which flows into Coyote Creek. The Guadalupe River crosses the southwesternmost corner and Upper Penitencia Creek crosses the northwesternmost corner of the quadrangle.

Major freeways in the San Jose East Quadrangle include the Bayshore (U.S. Highway 101), which leads northwest to the San Francisco Peninsula, and the Junipero Serra (Interstate 280), which intersects Highway 101 in the northwestern part of the quadrangle. Where the two intersect, I-280 becomes I-680, a conduit to eastern San Francisco Bay Area cities. State highways 85 and 87 cross the southwestern corner of the quadrangle, and highways 82 and 101 cross the southern boundary and continue southeastward.

GEOLOGIC CONDITIONS

Geologic Mapping

Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. To identify and characterize deposits susceptible to liquefaction in the San Jose East Quadrangle, recently completed mapping of the nine-county San Francisco Bay Area showing Quaternary deposits (Knudsen and others, 2000) and bedrock units (Wentworth and others, 1999) was obtained from the U.S. Geological Survey in digital form. These Geographic Information System (GIS) maps were combined to form a single, 1:24,000-scale geologic map of the San Jose East Quadrangle. This map (Plate 1.1) was used to evaluate liquefaction susceptibility and develop the Seismic Hazard Zones map.

Quaternary geologic mapping methods described by Knudsen and others (2000) consist of interpretation of topographic maps, aerial photographs, and soil surveys, as well as compiled published and unpublished geologic maps. The authors estimate the ages of deposits using: landform shape, relative geomorphic position, cross-cutting relationships, superposition, depth and degree of surface dissection, and relative degree of soil-profile development. The stratigraphic nomenclature used in Knudsen and others (2000) is compared to nomenclature used in several previous studies performed in northern California in Table 1.1.

Other geologic maps and reports were reviewed to evaluate the areal and vertical distribution of shallow Quaternary deposits and to provide information on subsurface geologic, lithologic and engineering properties of the units. Among the references consulted were: Crittenden (1951), California Department of Water Resources (1967), Helley and Brabb (1971), Poland (1971), Dibblee (1972), Nilsen and Brabb (1972), Brown and Jackson (1973), Cooper-Clark and Associates (1974), Rogers and Williams (1974), Atwater and others (1976), Helley and others (1979), Falls (1988), Helley (1990), Helley and Wesling (1990), Geomatrix Consultants Inc. (1992a, 1992b), and Helley and others (1994). Limited field reconnaissance was conducted to confirm the location of geologic contacts, map recently modified ground surfaces, observe properties of near-surface deposits, and characterize the surface expression of individual geologic units.

UNIT	Knudsen and others (2000)	Helley and others (1994)	Helley and others (1979)	Wentworth and others (1999)	DMG GIS database
Artificial fill	af			af	af
Gravel quarries and percolation ponds	gq	PP,GP		PP,GP	gq
Artificial stream channel	ac				ac
Modern stream channel deposits	Qhc	Qhsc	Qhsc	Qhc	Qhc
Latest Holocene alluvial fan levee deposits	Qhly				Qhly
Latest Holocene stream terrace deposits	Qhty				Qhty
Holocene basin deposits	Qhb	Qhb		Qhb	Qhb
Holocene alluvial fan deposits	Qhf	Qhaf, Qhfp		Qhf, Qhfp	Qhf
Holocene alluvial fan deposits, fine grained facies	Qhff	Qhfp			Qhff
Holocene alluvial fan levee deposits	Qhl	Qhl		Qh1	Qhl
Holocene stream terrace deposits	Qht	Qhfp		Qht	Qht
Holocene alluvium, undifferentiated	Qha			Qha	Qha
Late Pleistocene to Holocene alluvial fan deposits	Qf				Qf
Late Pleistocene to Holocene alluvial fan levee deposits	Ql				Ql
Late Pleistocene to Holocene stream terrace deposits	Qt				Qt
Late Pleistocene to Holocene alluvium, undifferentiated	Qa			Qa	Qa
Late Pleistocene basin deposits	Qpb				Qpb
Late Pleistocene alluvial fan deposits	Qpf	Qpaf		Qpf	Qpf
Early to middle Pleistocene alluvial fan deposits	Qof		Qof		Qof
Early to middle Pleistocene undifferentiated alluvial deposits	Qoa	Qru, Qrl	Qoa	Qpa	Qoa
bedrock	br	br			br

Table 1.1 Correlation Chart Showing Relationships among Quaternary Stratigraphic Nomenclature Used in Previous Studies. For this study, DMG has adopted the nomenclature of Knudsen and others (2000).

Regional Geology

Bedrock in the San Jose East Quadrangle consists of Mesozoic terranes overlain by Cenozoic strata on faulted unconformities. The San Jose Foothills are composed of steeply east-dipping Jurassic to Quaternary strata. The older strata are structurally repeated by steeply dipping, reverse-right-lateral faults (transpressive faults). The Silver Creek Hills contain Franciscan Complex basement rocks and Coast Range Ophiolite (Mesozoic terrane), which have been thrust over Cenozoic strata along the Silver Creek Fault (Wentworth and others, 1999). Cenozoic deposits include marine and non-marine units.

The San Jose East Quadrangle lies within the region affected by the active San Andreas Fault system, which distributes shearing across a complex assemblage of primarily right-lateral, strike-slip, parallel and sub-parallel faults that includes the Hayward and Calaveras faults. Western traces of a segment of the Calaveras Fault occur within the San Jose Foothills in the northeastern corner of the quadrangle. The Hayward Fault is farther west, near the base of the San Jose Foothills. The northwest-trending Silver Creek thrust fault bisects the Silver Creek Hills in the southeastern part of the quadrangle. Several smaller transpressive faults also are mapped within the quadrangle, primarily along the base of the San Jose Foothills. They include the Evergreen, Quimby, Piercy, and Clayton faults.

Surface Geology

Quaternary deposits cover approximately 60 percent of the San Jose East Quadrangle. These deposits fill the Santa Clara and Evergreen valleys, which make up the "South Bay Plain" in the vicinity of the quadrangle. There are also a few isolated Quaternary deposits in small upland valleys in the San Jose Foothills and Silver Creek Hills (Plate 1.1).

In general, Pleistocene alluvial fan and fluvial deposits are mapped along the eastern margin of the valley, near the base of the San Jose Foothills, and along the eastern and western edges of the Silver Creek Hills (Knudsen and others, 2000). Pleistocene alluvial fan remnants generally are above the valley floor and between streams that have deposited Holocene sediment on the alluvial plain at the base of the San Jose Foothills. A relatively large Pleistocene alluvial fan is associated with the Penitencia Creek drainage in the north-central area of the quadrangle. Pleistocene alluvial fans are differentiated from Holocene alluvial fans by their greater degree of surface dissection and relative degree of soil profile development (Knudsen and others, 2000).

The majority of Quaternary deposits within the San Jose East Quadrangle are within the gently northwest-sloping floor of the Santa Clara Valley. Several large streams in the valley, with channels as deep as 30 feet, are the sources for most of the sediment deposition within the quadrangle. All of the major drainages (Coyote Creek, Guadalupe River, and Thompson Creek) flow to the northwest and eventually empty into San Francisco Bay. Thompson Creek is joined by Yerba Buena Creek in Evergreen Valley in the southeastern part of the quadrangle where the sediment consists of late Pleistocene to Holocene alluvial fan deposits that interfinger with Holocene fan deposits coming out of the Foothills (Plate 1.1). Coyote Creek is the largest drainage in the area. Numerous Holocene fluvial terraces and well-defined Holocene levees flank Coyote Creek. The Holocene levee deposits result from Coyote Creek depositing overbank sediment adjacent to the channel during large floods. They are primarily long, low ridges that are evident on topographic maps. The Guadalupe River, which crosses the southwestern corner of the quadrangle, also has formed numerous Holocene fluvial terraces and Holocene levees. The very gently sloping northwestern part of the quadrangle is mapped as Holocene alluvial fan deposits and Holocene alluvial fan fine-facies deposits. These alluvial fan deposits are associated with the distal portion of the alluvial system and are primarily fine-grained material. The south-central portion of the quadrangle contains Holocene alluvial fan fine-facies material captured in a basin created by a series of low hills (Plate 1.1).

A few areas of historic artificial fill are mapped within the valley floor. The recently completed Lake Cunningham recreational area near the center of the quadrangle is one of the larger areas of artificial fill. Large areas of artificial fill also are mapped near Coyote Creek in the south-central part of the map (Plate 1.1). Thin artificial fill deposits (sliver fills) are present throughout the area, along the valley margins. These sliver fills are associated with residential and commercial construction and are too small to map at 1:24,000 scale.

Subsurface Geology and Geotechnical Characteristics

Information on subsurface geology and engineering characteristics of flatland deposits was obtained from borehole logs collected from geotechnical and environmental reports. For this investigation, about 200 borehole logs were collected from the files of the California Department of Transportation and the City of San Jose Department of Public Works (Plate 1.2). Data from 187 borehole logs were entered into a DMG geotechnical GIS database (Table 1.2). Additional ground-water information from approximately 140 boreholes within the San Jose East Quadrangle was obtained from the Santa Clara Valley Water District, Underground Storage Tank Monitoring Program.

Standard Penetration Test (SPT) (ASTM D 1586) data provide a standardized measure of the penetration resistance of a geologic deposit, and commonly are used as an index of density. Geotechnical investigations record SPT data including the number of blows of a drop hammer required to drive a sampler of assigned dimensions into the soil a distance of 1 foot. Recorded blow counts for non-SPT geotechnical sampling, where the sampler diameter, hammer weight or drop distance differ from those specified for a SPT, were converted to SPT blow counts and entered into the DMG GIS. The actual and converted SPT blow counts were normalized using the effective overburden pressure for each sample and adjusted for equipment and operational procedures using a method described by Seed and Idriss (1982), Seed and others (1985), and Youd and Idriss (1997). This normalized blow count is identified as $(N_1)_{60}$.

Geotechnical and environmental borehole logs provided lithologic and engineering characteristics of Quaternary deposits within the study area. All materials identified in the borehole logs were assigned unit names based on the unit descriptions of Knudsen and others (2000) as well as characteristics identified in the field. Geotechnical characteristics of the units are presented in Tables 1.2 and 1.3.

GEOLOGIC MAP UNIT		DRY DENSITY (pounds per cubic foot)						STANDARD PENETRATION RESISTANCE (blows per foot, $(N_1)_{60}$)					
Unit (1)	Texture (2)	Number of Tests	Mean	S (3)	Median	Min	Max	Number of Tests	Mean	S (3)	Median	Min	Max
Af	Fine	8	105	14.5	107	74	119	14	31	19	30	9	64
	Coarse	2	116.2	5	116.2	112.6	119.7	3	24	16	25	7	39
Ac	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qhc	Fine	1	108	0	108	108	108	2	32	1	32	31	33
	Coarse	5	109.1	8.9	108.6	98.7	122.6	12	22	11	19	11	49
Qhly	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	1	28	-	-	-	-
Qhty	Fine	0	-	-	-	-	-	4	13	8	13	4	24
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qhb	Fine	6	98.5	8.2	101.4	86.5	106	11	35	38	8	2	>99
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qhf	Fine	119	102.7	7.1	103.3	84.5	119.4	226	20	17	16	3	>99
	Coarse	51	102.7	7.3	101	87	125	129	27	23	20	5	>99
Qhff	Fine	36	105.8	7.9	107.1	90.8	122.7	73	22	18	18	3	>99
	Coarse	0	-	-	-	-	-	1	6	-	-	-	-
Qhl	Fine	94	103.6	7.9	103.4	85	131	140	18	12	15	3	75
	Coarse	26	101.8	7.2	101	91.6	119.1	50	16	9	15	2	56
Qht	Fine	1	96	-	96	96	96	2	22	5	22	19	25
	Coarse	0	-	-	-	-	-	3	37	12	38	24	48
Qha	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qf	Fine	28	104.3	9.6	104	79	122	23	24	18	17	4	68
	Coarse	3	88.4	14.6	86.3	75	104	18	12	5	11	6	21
Ql	Fine	4	93.5	5.1	95.5	86	97	10	14	18	8	5	64
	Coarse	0	-	-	-	-	-	2	14	1	14	13	15
Qt	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qa	Fine	2	102.6	-	102.6	102	103.2	2	33	1	33	32	34
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qpb	Fine	0	-	-	-	-	-	1	36	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qpf	Fine	69	108	10.1	110.7	79.5	125	122	28	23	22	5	>99
	Coarse	31	109.7	10.4	109	87.6	131	80	39	27	34	6	>99
Qof	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-
Qoa	Fine	0	-	-	-	-	-	0	-	-	-	-	-
	Coarse	0	-	-	-	-	-	0	-	-	-	-	-

Notes:

(1) See Table 1.3 for names of the units listed here

(2) Fine soils (silt and clay) contain a greater percentage passing the #200 sieve (<.074 mm); coarse soils (sand and gravel) contain a greater percentage not passing the #200 sieve.

(3) S = standard deviation.

Table 1.2 Geotechnical Characteristics of Quaternary Geological Units in the San Jose East Quadrangle.

Geologic Unit (1)	Description	Number of Records	Composition by Soil Type (Unified Soil Classification System Symbols) (2)	Depth to ground water (ft) (3) and liquefaction susceptibility category assigned to geologic unit			
				<10	10 to 30	30 to 40	>40
af	Artificial fill (4)	30	CL 53%; ML 20% GW 14%; Other 13%	VH - L	H - L	M - L	VL
ac	Artificial stream channel	0	n/a	VH	H	M	VL
Qhc	Modern stream channel deposits	11	GW 27%; SM 27%; SP 18%; Other 28%	VH	H	M	VL
Qhly	Latest Holocene alluvial fan levee deposits	1	SC	VH	H	M	VL
Qhty	Latest Holocene stream terrace deposits	3	CL 67%; GW 33%	H	H	M	VL
Qhb	Holocene basin deposits	7	CL 57%; CH 29% ML 14%	M	L	L	VL
Qhf	Holocene alluvial fan deposits	357	CL 41%; ML 19% SM 17%; Other 23%	H	M	L	VL
Qhff	Holocene alluvial fan deposits, fine grained facies	63	CL 75%; ML 17% Other 8%	M	M	L	VL
Qhl	Holocene alluvial fan levee deposits	186	CL 46%; ML 29% SM 14%; Other 11%	H	M	L	VL
Qht	Holocene stream terrace deposits	8	GM 25%; Other 75% (one sample each of SP, SC, SM, ML, CL, GP)	H	H	M	VL
Qha	Holocene alluvium, undifferentiated	0	n/a	M	M	L	VL
Qf	Late Pleistocene to Holocene alluvial fan deposits	49	CL 45%; SM 20% SC 12%; Other 23%	M	L	L	VL
Ql	Late Pleistocene to Holocene alluvial fan levee deposits	16	CL 50%; ML 38% Other 12%	M	L	L	VL
Qt	Late Pleistocene to Holocene stream terrace deposits	0	n/a	M	L	L	VL
Qa	Late Pleistocene to Holocene alluvium, undifferentiated	2	CL 100%	M	L	L	VL
Qpb	Late Pleistocene basin deposits	1	CL 100%	L	L	VL	VL
Qpf	Late Pleistocene alluvial fan deposits	262	CL 39%; ML 15%; SM12%, GP 9%; SC 7%; Other 34%	L	L	VL	VL
Qof	Early to middle Pleistocene alluvial fan deposits	4	CL 25%; ML 25% GP 25%; SM 25%	L	L	VL	V L
Qoa	Early to middle Pleistocene alluvium, undifferentiated	0	n/a	L	L	VL	VL
B	Bedrock	n/a	n/a	VL	VL	VL	VL

Notes:
(1) Susceptibility assignments are specific to the materials within the San Jose East 7.5 minute Quadrangle.
(2) n/a = not applicable
(3) Based on the simplified Seed approach and a small number of borehole analyses for some units.
(4) The liquefaction susceptibility of artificial fill ranges widely, depending largely on the nature of the fill and whether it was compacted during emplacement.

Table 1.3 Liquefaction Susceptibility for Units Within the San Jose East 7.5 -Minute Quadrangle. Units indicate relative susceptibility of deposits to liquefaction as a function of material type and ground-water depth

within that deposit. VH = very high, H = high, M = moderate, L = low, and VL = very low to none.

GROUND-WATER CONDITIONS

Liquefaction hazard exists in areas where depth to ground water is 40 feet or less. Accordingly, ground-water conditions were investigated in the San Jose East Quadrangle to evaluate the depth to saturated sediment. Saturated conditions reduce the normal effective stress, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). The evaluation of depth to ground water was based on first-encountered water in geotechnical borehole logs acquired from the City of San Jose and water-level data provided by the Santa Clara Valley Water District. The depths to first-encountered water, free of piezometric influences, were plotted onto a map of the project area along with depths to historically shallowest ground water (Plate 1.2). Depth to the water surface in stream channels, creeks, and drainage ditches was observed in the field.

CDMG uses the historically highest known ground-water levels because water levels during an earthquake can not be anticipated due to fluctuations caused by natural variations and human activities. A historically high ground-water map differs from most ground-water maps, which show the actual water table at a particular time, this map depicts a hypothetical ground-water table. Ground-water levels are presently at or near their historic highs in many areas of the Santa Clara Valley. The Santa Clara Valley Water District recently has observed an increasing number of artesian wells, which is indicative of rising ground-water levels (SCVWD, personal communication). Regional ground-water contours on Plate 1.2 show historic-high water depths, as interpreted from borehole logs from 1953 to the present.

Depths to first-encountered water range from 1 to 71 feet below the ground surface and most of the valley floor has ground-water levels within 40 feet of the ground surface (Plate 1.2). Evergreen Valley, near the base of the San Jose Foothills, has ground-water levels between 10 and 30 feet below the ground surface. Santa Clara Valley in the central and northwest part of the quadrangle has ground-water levels within 10 feet of the ground surface. Along the southern part of the quadrangle a separate basin with ground-water levels less than 20 feet below the ground surface is evident. A single area of deeper ground water occurs west of the northern tip of the Silver Creek Hills (Plate 1.2).

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. Application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of liquefaction potential of geologic materials. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). It includes combining geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates and follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude used in DMG's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the San Jose East Quadrangle, PGA's of 0.55 to 0.76 g, resulting from earthquakes of magnitude 6.4 to 7.9, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996). See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. Some of these properties can be correlated with geologic age and environment of deposition. With increasing age of a deposit, relative density may increase through cementation of the particles or the natural compaction due to the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although varieties of silt with low plasticity are treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher penetration resistances generally result in lower liquefaction susceptibility. Different blow count corrections are used for silty sand and nonplastic silt than for clean sand (Seed and others, 1985). Blow-count and cone-penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (a sample is more likely to liquefy). Soils that lack resistance (susceptible soils) are typically saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-properties and soil-conditions such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps. DMG's qualitative susceptibility inventory is summarized in Table 1.3.

Most Holocene materials where water levels are within 30 feet of the ground surface have susceptibility assignments of high (H) to very high (VH) (Table 1.3). Holocene basin deposits (Qhb), Holocene alluvial fan fine facies deposits (Qhff), and undifferentiated Holocene alluvium (Qha) were determined to be primarily composed of fine-grained material in this area and have correspondingly lower susceptibility assignments. However, these units may contain lenses of material with higher liquefaction susceptibility. All late Pleistocene and older deposits within 30 feet of the ground surface have low (L) susceptibility assignments except late Pleistocene to Holocene alluvial fan levee deposits (Ql), late Pleistocene to Holocene undifferentiated alluvium (Qa) and late Pleistocene to Holocene stream terrace deposits (Qt). These units were determined to have sufficiently low densities along with lenses of potentially liquefiable material that could liquefy (Table 1.3). Uncompacted artificial fill and latest Holocene alluvial fan levee and stream terrace deposits have moderate (M) susceptibility assignments where they are saturated between 30 and 40 feet. All other units have low (L) to (VL) susceptibility assignments below 30 feet of the ground surface.

QUANTITATIVE LIQUEFACTION ANALYSIS

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). The Seed Simplified procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the “trigger” for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures. The DMG liquefaction analysis program calculates an FS value for each geotechnical sample for which blow counts were collected. Typically, multiple samples are collected from each borehole. The lowest FS in each borehole is used for that location. These FS values vary in reliability according to the quality of the geotechnical data used in their calculation. These FS values, as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation**.**

Of the 187 geotechnical borehole logs reviewed in this study (Plate 1.2), 172 include blow-count data from SPT’s or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside-diameter ring samplers, were translated to SPT-equivalent values where reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc.) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using average test values of similar materials.

The liquefaction evaluation procedures used in the Seed Simplified Analysis were developed primarily for clean sands and silty sands. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts (N) using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant gravel content. In the past, gravelly soils were not considered to be susceptible to liquefaction because the high permeability of such soils would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during many earthquakes and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy, Campanella, and Stewart, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes.

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of State Mining and Geology Board criteria to liquefaction zoning in the San Jose East Quadrangle is summarized below.

Areas of Past Liquefaction

Tinsley and others (1998) compiled observations of evidence for liquefaction in the San Jose East Quadrangle for the 1989 Loma Prieta earthquake, and Youd and Hoose (1978) compiled them for the 1868 and 1906 earthquakes. No observations of liquefaction in the San Jose East Quadrangle were recorded following the 1989 Loma Prieta earthquake. Youd and Hoose (1978) report that following the 1906 earthquake, in an indistinct area along Coyote Creek, numerous cracks were observed on both sides of the creek from Milpitas "all the way to San Jose" as recorded in Lawson (1908). They also report that within the valley no cracking was observed along Alum Rock Road east of Coyote Creek. Very few observations of the 1868 Hayward earthquake record specific evidence for liquefaction. However, Lawson (1908) reports a story from a survivor of the 1868 earthquake, Mrs. N. Ainsworth, in which she states by second hand information that "water spurted up in the streets of San Jose, and out in the road between Milpitas and San Jose, to the height of several feet."

Areas with Sufficient Existing Geotechnical Data

Borehole logs that include penetration test data and reasonably sufficient lithologic descriptions were used to evaluate liquefaction potential. The areas with sufficient geotechnical data are evaluated for zoning based on the liquefaction potential determined by the Simplified Seed procedure. According to the borehole data analyzed using the Seed Simplified Procedure, Holocene alluvial deposits that cover much of the Santa Clara Valley floor contain material that could liquefy under expected earthquake ground motion and are zoned accordingly.

Along the base of the San Jose Foothills in the northeastern portion of the San Jose East Quadrangle, the liquefaction zone boundaries are delineated by the depth to denser material, primarily late Pleistocene alluvial fan deposits (Qpf), and the depth to ground water. Where lower density, younger material is above the water table (e.g. unsaturated), these areas are excluded from the zone.

The areas of the San Jose East Quadrangle mapped as Holocene alluvial fan deposits (Qhf), Holocene basin deposits (Qhb), and Holocene alluvial fan, fine facies (Qhff) are included in the liquefaction zones where they are saturated above 40 feet. These units have a relatively small percentage of sandy and/or gravelly deposits; however, they do contain layers of fine sand and silt. In a fluvial environment, the potentially liquefiable layers are often discontinuous and lens-shaped deposits, which may not have been sampled by the geotechnical investigations evaluated by our regional analysis.

Areas with Insufficient Existing Geotechnical Data

Adequate geotechnical borehole information for Quaternary geologic units including: late Pleistocene to Holocene stream terrace deposits (Qt); late Pleistocene to Holocene alluvium, undifferentiated (Qa); Holocene stream terrace deposits (Qht); Holocene alluvium, undifferentiated (Qha); and modern stream channel deposits (Qhc), in canyon areas along and within stream channels generally is lacking. Soil characteristics for these units are assumed to be similar to deposits where subsurface information is available. These deposits, therefore, are included in the liquefaction zone for reasons presented in criterion 4-a, above.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the San Jose East 7.5-Minute Quadrangle, Santa Clara County, California

By
Mark O. Wiegers, Kent Aue, and Timothy P. McCrink

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by DMG in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the San Jose East 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1, addressing liquefaction, and Section 3, addressing earthquake shaking, form a report that is one of a series of reports that summarize the development of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous large, active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the San Jose East Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the San Jose East Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic and geologic conditions are covered in Part I; ground shaking opportunity, landslide hazard potential and zoning evaluations are covered in Part II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The San Jose East Quadrangle covers approximately 62 square miles in the southeastern San Francisco Bay Area within central Santa Clara County. Plate 2.1 shows major topographic features and transportation routes in the study area. The quadrangle covers part of the City of San Jose and unincorporated Santa Clara County land. Most of the low-lying areas on the valley floor and some of the hillside areas are within the City of San Jose. The less densely developed hillsides in the eastern and southeastern parts of the quadrangle and several small areas on the valley floor are unincorporated county areas. The City of San Jose and Santa Clara County civic centers are approximately 2 miles west of the quadrangle boundary, within the San Jose West Quadrangle.

The western half of the quadrangle is occupied by the floor of the Santa Clara Valley, except for a small hilly area near the western boundary of the quadrangle. The main drainage on the valley floor is Coyote Creek, which extends north-northwesterly across the valley floor and drains into the southern end of San Francisco Bay. Several smaller streams and tributaries to Coyote Creek also drain the valley floor and the adjacent hills. Many smaller drainages in urbanized areas have been modified by construction of culverts and engineered channels.

Most of the western half of the quadrangle consists of an alluvial plain that is part of the Santa Clara Valley. This part of the Santa Clara Valley is drained by Coyote Creek, which flows diagonally across the entire quadrangle in the central part of the map area. South of Coyote Creek there are a few hills. West-facing slopes of the Diablo Range, called the San Jose Foothills in this area, rise above the valley in the eastern half of the quadrangle. The southeastern part of the quadrangle also includes a series of moderately steep hills that flank a narrow, northwest-trending linear valley drained by Silver Creek. Yerba Buena Ridge lies on the southwest side of Silver Creek. Also in the southeastern part of the quadrangle is Evergreen Valley, an extension of the Santa Clara Valley that lies between the Diablo Range and the Silver Creek hills. Evergreen Valley is drained by Thompson Creek, a major tributary to Coyote Creek.

Several freeways and major highways traverse the western half of the quadrangle. U.S. Highway 101 crosses the quadrangle diagonally from the northwest corner to the south-central boundary. Capitol Expressway and Monterey Road (State Highway 82) run subparallel to U.S. 101 for most of this distance. Interstate Highways 280 and 680 intersect U.S. 101 in the northwestern quadrant of the quadrangle. Several secondary roads provide access to the eastern half of the quadrangle.

Suburban residential and commercial development covers much of the valley floor in the San Jose East Quadrangle and extends into portions of the adjoining hills. Some hillside areas in the northeastern and southeastern corners of the quadrangle remain sparsely developed. Urban uses have displaced agricultural land uses in many parts of the quadrangle. Large-scale grading has modified considerable portions of Yerba Buena

Ridge and Silver Creek Valley, as well as some of the lower slopes of the Diablo Range. Residential and commercial uses will likely expand further in some parts of the San Jose East Quadrangle.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

The primary source of bedrock geologic mapping used in this slope stability evaluation was obtained from the digital database "Preliminary Geologic Map of the San Jose 30 x 60 minute Quadrangle" prepared by the U.S. Geological Survey (Wentworth and others, 1999b). The 1:24,000-scale geology of the San Jose East 7.5-minute Quadrangle was obtained from this database. The surficial geologic mapping for the San Jose East Quadrangle was prepared by Knudsen and others (2000) at a scale of 1:24,000 and digitized by the U.S. Geological Survey. Surficial geology is discussed in detail in Section 1 of this report.

DMG geologists merged the surficial and bedrock geologic map databases and contacts between them were modified in some areas to resolve differences. Geologic reconnaissance was performed to assist in adjusting contacts and to review the lithology of geologic units and geologic structure.

Bedrock of the San Jose East Quadrangle consists of two juxtaposed Mesozoic terranes that are overlain by Cenozoic strata along a faulted angular unconformity (Graymer, 1995). The two Mesozoic terranes are the Coast Range Ophiolite, with the overlying Great Valley Sequence, and the Franciscan Complex. Cenozoic units include marine and non-marine deposits ranging from mid-Miocene to Holocene in age.

The bedrock sequences in the 30 x 60-minute San Jose Quadrangle have been divided into eight individual fault-bounded structural blocks based on differing stratigraphic sequences and geologic history (Wentworth and others, 1999a). Three of these structural blocks extend into the San Jose East 7.5-minute Quadrangle. These blocks include: (1) the Silver Creek Block, which underlies Yerba Buena Ridge and the hills along Silver Creek in the southeastern part of the quadrangle; (2) the Alum Rock Block, which underlies the southwestern flank of the Diablo Range in the eastern part of the quadrangle; and, (3) the Mt. Hamilton Block, which forms the core of the Diablo Range and extends into the extreme northeastern corner of the quadrangle. The following descriptions of bedrock units in the San Jose East Quadrangle are based primarily on Wentworth and others (1999a) and on field reconnaissance by DMG geologists.

The oldest rocks in the study area are Jurassic rocks of the Coast Range Ophiolite (Jsp) and the overlying Jurassic to Lower Cretaceous rocks of the Knoxville Formation (KJk). The Coast Range Ophiolite consists primarily of serpentinite in the study area with some massive serpentinized harzburgite in the Silver Creek area. The Coast Range Ophiolite also contains basalt near the southern part of the quadrangle. Silica-carbonate rock is associated with the serpentinite in the Silver Creek area. The silica-carbonate rock likely was formed by Miocene hydrothermal alteration of serpentinite (DeVito, 1995). The serpentinite and basalt rocks exposed in the Silver Creek area are relatively hard and resistant to erosion. In contrast, serpentinite exposures on the southwest flank of the Diablo Range are weaker, highly sheared and less resistant to erosion. The Jurassic Knoxville Formation overlies the Coast Range Ophiolite and is exposed in the Silver Creek area. The unit consists mainly of dark, greenish-gray shale with thin sandstone interbeds.

The Franciscan Complex (fm) is exposed in each of the three bedrock structural blocks within the San Jose East Quadrangle. In the Silver Creek area, it is juxtaposed against the Coast Range Ophiolite along a prominent low-angle thrust fault. This fault is part of a regional system of faults called the Coast Range Thrust, which formed during late Mesozoic and early Cenozoic subduction along the western edge of the North American Plate. In the study area, the Franciscan Complex consists of a highly sheared matrix of shale, graywacke or metagraywacke that contains an assortment of blocks and slabs of numerous rock types, including metagraywacke, argillite, chert, serpentinite, greenstone, amphibolite, tuff, eclogite, quartz schist, greenschist, basalt, marble, conglomerate, and blueschist. Individual blocks range in length from less than an inch to several hundred feet. Only some of the largest individual blocks in the Silver Creek area are shown on the digital geologic map used for this study.

The Cretaceous Berryessa Formation is part of the Great Valley Sequence and is exposed on the lower flanks of the Diablo Range. It is divided into a basal conglomerate unit (Kbc) and an overlying sandstone and mudstone unit (Kbs). The conglomerate (Kbc) occurs as thick, indistinct beds with pebble, cobble, and occasional boulder clasts, intercalated with coarse-grained mica-quartz-lithic wacke. Clasts include silicic to intermediate volcanic rocks, black chert and argillite, quartz, mica schist, meta-andesite, granodiorite and granite, black hornfels, and rip-up clasts of mudstone and lithic wacke. The sandstone and mudstone unit (Kbs) consists of layers of massive, indistinctly bedded, coarse- to fine-grained, mica-quartz-lithic wacke interbedded with poorly bedded mica-bearing siltstone and claystone. Locally, small lenses of conglomerate occur within the sandstone and mudstone unit.

The oldest Cenozoic unit exposed in the San Jose East Quadrangle is the Middle to Upper Miocene Claremont Formation (Tcc). The Claremont Formation consists primarily of interbedded chert and siliceous shale. Siltstone and fine-grained quartz sandstone are locally present. The Claremont Formation is exposed on the western flank of the Diablo Range.

The Upper Miocene Briones Formation (Tbr) unconformably overlies the Claremont Formation. It consists of interbedded sandstone and siltstone, shell-hash conglomerate, cross-bedded sandstone, and occasional pebble and cobble conglomerate beds. The lower part is thin-bedded, fine-grained sandstone and shale interbedded with thick, massive sandstone beds. Indistinctly bedded conglomeratic shell beds occur in the middle part of this unit and are characteristic of this formation. The shell-rich beds typically form prominent ridges and peaks due to a resistant calcareous matrix. The upper part of the unit consists of distinctly to indistinctly bedded, massive to cross-bedded, fine- to coarse-grained sandstone. The Briones Formation is exposed over a large area on the southwest flank of the Diablo Range in the San Jose East Quadrangle.

An unnamed Miocene sandstone unit (Tso) and an overlying andesite (Tvo) crop out in a small area near Silver Creek in the southeastern part of the quadrangle. The sandstone is biotite-rich with a thin layer of peat near its top. The age of the unit was determined from a potassium/argon age date from a thin silicic tuff bed (Nakata and others, 1993). The overlying andesite of Silver Creek includes both andesite and basalt dikes and flows interbedded with tuff.

The non-marine upper Miocene Orinda Formation (Tor) is exposed in a small area on the southwestern side of the Diablo Range. It is comprised of non-marine pebble to boulder conglomerate, conglomeratic sandstone, and coarse- to medium-grained lithic sandstone. The unit includes inter-layered basalt and andesite flows and sills (Torv) that are exposed in a small area in the northeastern part of the quadrangle.

The Upper Miocene to Pliocene Silver Creek Gravels (Tsg) are exposed along the northeast side of Silver Creek in the southeastern part of the quadrangle. This unit consists of interbedded conglomerate, sandstone, siltstone, tuffaceous sediment, tuff and basalt. It is distinguished from similar gravels by the presence of interbedded white tuffs and other volcanic rocks, beds of nonmarine red and green mudstone, by the relatively well-consolidated nature of the conglomerate beds, and by its characteristic clast composition. About 75 percent of the clasts are Franciscan Complex rocks with the remaining 25 percent consisting of volcanic rocks, Claremont siliceous shale and chert, and other Cenozoic rocks.

The Plio-Pleistocene Packwood Gravels (QTp) consist of silty and fine sandy pebble conglomerate, fine silty sandstone, pebbly to fine sandy siltstone, and minor olive-green claystone beds. Numerous nonmarine red mudstone beds are also present. Most of the clasts are derived from rocks of the Great Valley Sequence rather than the Franciscan Complex. This unit is exposed along the northeastern side of Yerba Buena Ridge and overlies the Silver Creek Gravels along an angular unconformity in this area.

Unconsolidated Quaternary deposits underlie the floor of the Santa Clara Valley. A detailed discussion of Quaternary units can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units were ranked on the basis of their shear strength. Shear strength data for rock units identified on the geologic map were obtained from the City of San Jose, the County of Santa Clara and from the DMG Environmental Review Project (Appendix A). Generally, the primary source for the rock shear-strength measurements were geotechnical reports prepared by consultants that are on file with the City and County planning and permitting departments. The locations of rock and soil samples taken for shear testing are shown on Plate 2.1. Shear tests from the adjacent Calaveras Reservoir

Quadrangle were used to augment data for several geologic formations that had little or no shear test information available in the San Jose East Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean and median) phi values for each geologic unit are summarized in Table 2.1. A geologic material strength map was made based on the groupings presented in Tables 2.1 and 2.2. The geologic material strength map provides a spatial representation of material strength for use in the slope stability analysis.

For most of the geologic units in the map area, a single shear strength value was assigned and used in our slope stability analysis. The shear strength value assigned to each unit was based on the statistical average of phi values obtained from the collected laboratory test data. Two units, the Briones Formation (Tbr) and ultramafic rocks of the Coast Range Ophiolite (Jsp) were subdivided further, as discussed below.

The Briones Formation, which contains interbedded sandstone and shale, was subdivided based on shear strength differences between coarse-grained (higher strength) and fine-grained (lower strength) lithologies. Shear strength values for the coarse- and fine-grained lithologies were then applied to areas of favorable and adverse bedding orientation, respectively. Such areas were determined from structural and terrain data as discussed in the following section (see ”Structural Geology” below). It was assumed that coarse-grained material (higher strength) dominates where bedding dips into a slope (favorable bedding), whereas fine-grained (lower strength) material dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength value to areas where adverse bedding was identified.

Ultramafic rocks of the Coast Range Ophiolite were subdivided on the basis of observed differences in rock strength between outcrops in the Silver Creek Block in the Silver Creek area, and those in the Alum Rock Block on the southwestern flank of the Diablo Range. Field observation of outcrops of ultramafic rocks and basalt in the Silver Creek Block showed them to be comprised of rocks that are relatively strong and unweathered, with little soil development and few landslides. Shear strength tests on intact, non-sheared ultramafic rocks were used to develop the characteristic phi value for ultramafic rock and basalt in the Silver Creek Block. In contrast, outcrops of ultramafic rocks in the Alum Rock Block were observed to consist of relatively weak, highly sheared and deeply weathered rock. The overall strength of the ultramafic rocks within the Alum Rock Block is the result of a mixture of large blocks in a sheared matrix. The engineering characteristics of block-in-matrix rocks, or “bimrocks,” have been described by several workers (for example, Medley, 1994; 1999). The phi values for both sheared and intact ultramafic materials were combined to develop a generally lower characteristic phi value for the block-in-matrix ultramafic rocks observed in the Alum Rock Block.

SAN JOSE EAST QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Tbr(fbc)	2	38/38	38/38	139/139		38
GROUP 2	Jsp(SCB)	16	34/33	34/35	645/620	Jbk	34
	kJk	5	33/41			sc	
	Tsg	1	36/36				
GROUP 3	Tbr(abc)	5	23/28	26/24	802/750		26
	Jsp(ARB)	31	24/27				
	Kbs	22	26/25				
GROUP 4	fm	18	24/20	21/20	834/710	Tor	21
	Kbc	37	21/18			Torv	
	Tcc	16	20/20			Tso	
	QTp	75	23/21			Tvo	
	Qp	35	23/23			cg	
	Qh	52	21/20			ch	
						gs	
						sp	
GROUP 5	Qls	1	12	12-Jan	745		12

abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength
SCB - Silver Creek Block ARB - Alum Rock Block

Formations for strength groups from Wentworth and others (1999)
except Qls which is from landslide inventory prepared
for this study

Table 2.1. Summary of the Shear Strength Statistics for the San Jose East Quadrangle.

SHEAR STRENGTH GROUPS FOR THE SAN JOSE EAST 7.5-MINUTE QUADRANGLE

GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Tbr(fbc)	Jsp(SCB)	Tbr(abc)	fm	Qls
	Tsg	Jsp(ARB)	Kbc	
	KJk	Kbs	Tcc	
	Jbk		QTp	
	sc		Qp	
			Qh	
			Tor	
			Torv	
			Tvo	
			Tso	
			cg	
			ch	
			gs	
			sp	

Table 2.2. Summary of Shear Strength Groups for the San Jose East Quadrangle.

Structural Geology

The Mesozoic and Tertiary bedrock units in the San Jose East Quadrangle are intensely faulted and folded. Most of the major faults and fold axes trend northwestward. Sedimentary units generally dip moderately to steeply to the northeast and are locally overturned (Dibblee, 1972). Faults in the study area include transpressive faults, attenuation faults and strike-slip faults (Graymer, 1995). The Hayward fault has the most recent displacement of the faults in the region. Other notable faults in the study area include the Quimby, Evergreen, Silver Creek and Coast Range faults.

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can form along bedding surfaces that intersect the ground surface.

To account for adverse bedding in our slope stability evaluation, we used structural data from the geologic map database (Wentworth and others, 1999b), in combination with digital terrain data to identify areas with potentially adverse bedding. The methods used in this analysis are similar to those of Brabb (1983) and are briefly summarized as follows. First, the structural geologic data were used to categorize areas of common dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude was less than or equal to the slope gradient category but greater than 25% (4:1 slope) the area was marked as a potential adverse bedding area. As described in the previous section, a lower strength value was used for the slope stability analysis in selected areas with adverse bedding.

Landslide Inventory

To evaluate earthquake-induced landsliding, it is necessary to identify previous occurrences of landsliding in the study area. An inventory of existing landslides in the San Jose East Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published landslide mapping (Nilsen, 1975). Landslides were mapped and digitized at a scale of 1:24,000.

In general, landslides are abundant in many of the hillside areas in the San Jose East Quadrangle. Numerous large, deep-seated landslides are present on the southwestern flank of the Diablo Range. Smaller earthflows are abundant in areas underlain by Franciscan Complex rocks in the Silver Creek and Yerba Buena Ridge area. Landslides identified in the map area are shown on Plate 2.1.

Each of the landslides identified in the inventory was classified according to a three-fold rating of confidence of interpretation (definite, probable, or questionable). Landslides rated as definite and probable were assigned a low shear strength value (12 degrees) and carried into the slope stability analysis. The assigned phi value was based on the measured residual shear strength along the slip surface of a large landslide at the Penitentia Creek Water Treatment Plant, just north of the San Jose East Quadrangle. Landslides rated as questionable were not carried into the slope stability analysis due to the large element of uncertainty of their existence.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis requires the selection of a design earthquake strong-motion record. For the San Jose East Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.1
Modal Distance:	5.3 – 16.2 km
PGA:	0.55 – 0.79g

The strong-motion record selected for the slope stability analysis in the San Jose East Quadrangle was the Corralitos record from the magnitude 6.9 (M_w) 1989 Loma Prieta earthquake (Shakal and others, 1989). This record had a source to recording site distance of 5.1 km and a peak ground acceleration (PGA) of 0.64 g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

To develop a relationship between yield acceleration (a_y, defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.086, 0.13 and 0.23g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the San Jose East Quadrangle.

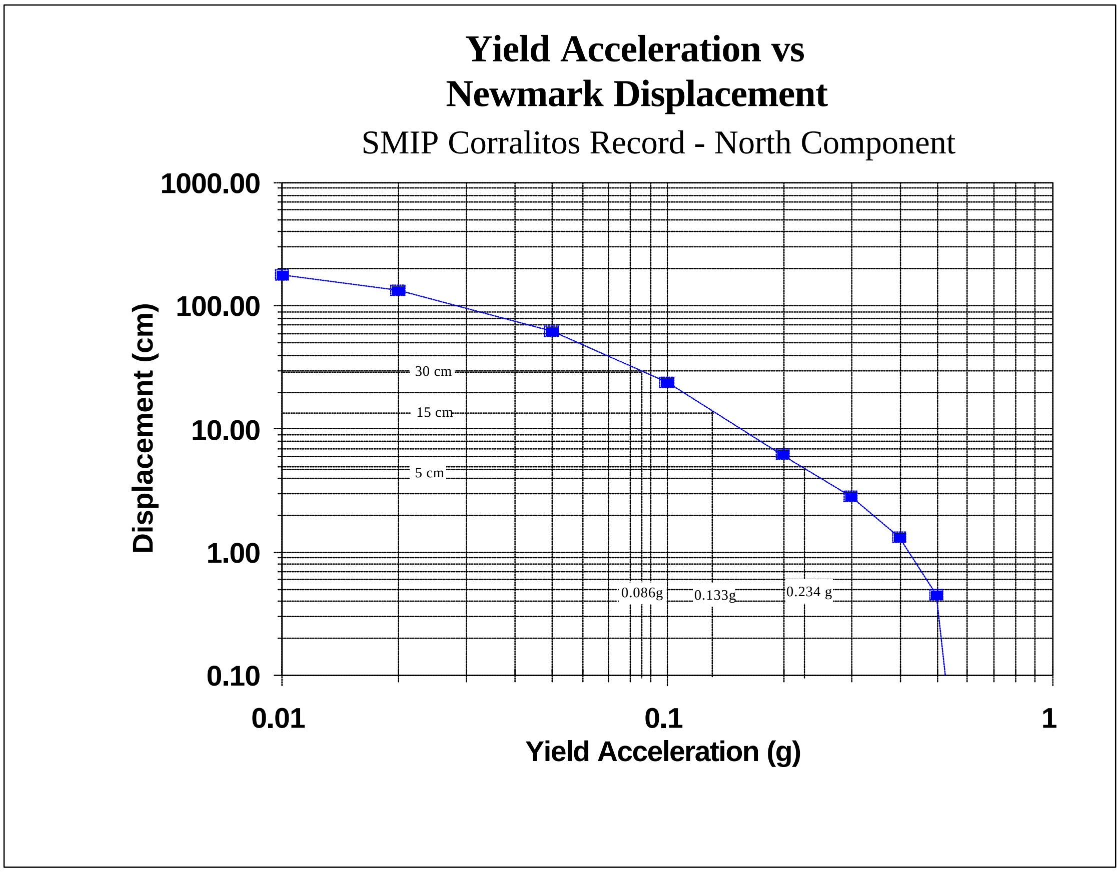

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1989 Loma Prieta Earthquake Corralitos Record. Record from California Strong Motion Instrumentation Program (CSMIP) Station 57007.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

Up-to-date digital terrain data were required to perform the slope stability analysis for this study. Terrain data used in this study were obtained from the U.S. Geological Survey and from commercially available interferometric synthetic aperture radar.

Terrain data obtained from the U.S. Geological Survey consisted of a Level 2 digital elevation model (DEM) prepared from the contours on the 7.5-minute quadrangle map. The U.S. Geological Survey DEM has10-meter horizontal resolution and a 7.5-meter vertical accuracy. These terrain data were used in flat-lying areas and hillside areas that have not been significantly altered by development. A program that adds pixels to the edges of the DEM was run to avoid the loss of data at the quadrangle edges when slope calculations were performed. A peak and pit smoothing process also was performed to remove errors in the elevation points.

To calculate slope gradient for hillside areas that have undergone large-scale grading, a digital elevation model (DEM) was obtained from an airborne interferometric radar platform flown in 1998, with an estimated vertical accuracy of approximately 2 meters (Intermap Corporation, 1999). The most significant large-scale grading has occurred in the hills in and adjacent to Silver Creek, where large residential developments and golf courses have recently been constructed. In addition, quarrying, road construction, and residential development have significantly modified hillside areas in the southwestern portion of the quadrangle. An interferometric radar DEM is prone to creating false topography where tall buildings, metal structures, or trees are present. Due to the prevalent grassy vegetation and relatively small residential-type buildings present in the hilly areas, this type of DEM is appropriate for use. Nevertheless, the final hazard zone map was checked for potential errors and corrected where necessary. Recently graded areas where radar terrain data were used are shown on Plate 2.1.

A slope map and a slope aspect map were made from each DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The slope map and the slope aspect map were used in conjunction with geologic structural data to identify areas of potential adverse bedding conditions, as previously discussed. The slope map also was used in conjunction with the geologic material strength map to produce the earthquake-induced landslide hazard potential map, as discussed below.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite-slope failure, α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.086g, Newmark displacements greater than 30 cm are indicated, and a HIGH hazard potential was assigned (H on Table 2.3).

2. If the calculated a_y fell between 0.086g and 0.13g, Newmark displacements between 15 cm and 30 cm are indicated, and a MODERATE hazard potential was assigned (M on Table 2.3).

3. If the calculated a_y fell between 0.13g and 0.23g, Newmark displacements between 5 cm and 15 cm are indicated, and a LOW hazard potential was assigned (L on Table 2.3).

4. If the calculated a_y was greater than 0.23g, Newmark displacements of less than 5 cm are indicated, and a VERY LOW potential was assigned (VL on Table 2.3).

Table 2.3 summarizes the results of the stability analyses. An earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

SAN JOSE EAST QUADRANGLE
HAZARD POTENTIAL MATRIX

		SLOPE CATEGORY (% SLOPE)								
GEOLOGIC STRENGTH GROUP	MEAN PHI	I 0 to 8%	II 8 to 14%	III 15 to 24%	IV 25 to 35%	V 36 to 42%	VI 43 to 51%	VII 52 to 62%	VIII 63 to 68%	IX >68%
1	38	VL	VL	VL	VL	VL	VL	VL	M	H
2	34	VL	VL	VL	VL	VL	L	H	H	H
3	26	VL	VL	VL	L	H	H	H	H	H
4	21	VL	L	L	H	H	H	H	H	H
5	12	M	H	H	H	H	H	H	H	H

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the San Jose East Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (1996). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail, as follows:

Existing Landslides

Existing landslides typically consist of disrupted soil and rock materials that are generally weaker than adjacent undisturbed materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most common in steep headscarp areas and at the toe of existing landslide deposits. Reactivation of deep-seated landslide deposits is less common (Keefer, 1984); however, deep-seated landslide movements were observed in the 1989 Loma Prieta and 1994 Northridge earthquakes. Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by DMG (McCrink and Real, 1996), it has been determined that earthquake-induced landslide hazard zones should encompass all areas that have a calculated displacement greater than 5 centimeters. This corresponds to High, Moderate or Low levels of hazard potential (see Table 2.3). Areas with a Very Low hazard potential, that is, less than 5 centimeters of calculated displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slope gradient categories. (Note: Geologic Strength Group 5 includes all mappable landslides with a definite or probable confidence rating).

2. Geologic Strength Group 4 is included for all slopes steeper than 15 percent.

3. Geologic Strength Group 3 is included for all slopes steeper than 25 percent.

4. Geologic Strength Group 2 is included for all slopes steeper than 43 percent.

5. Geologic Strength Group 1 is included for all slopes greater than 52 percent.

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AIR PHOTOS

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
County of Santa Clara	81
City of San Jose	225
DMG Environmental Review Project	12
Total Tests Used	318

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the San Jose East 7.5-Minute Quadrangle, Santa Clara County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles.

They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the “Simple Prescribed Parameter Value” method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG’s Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

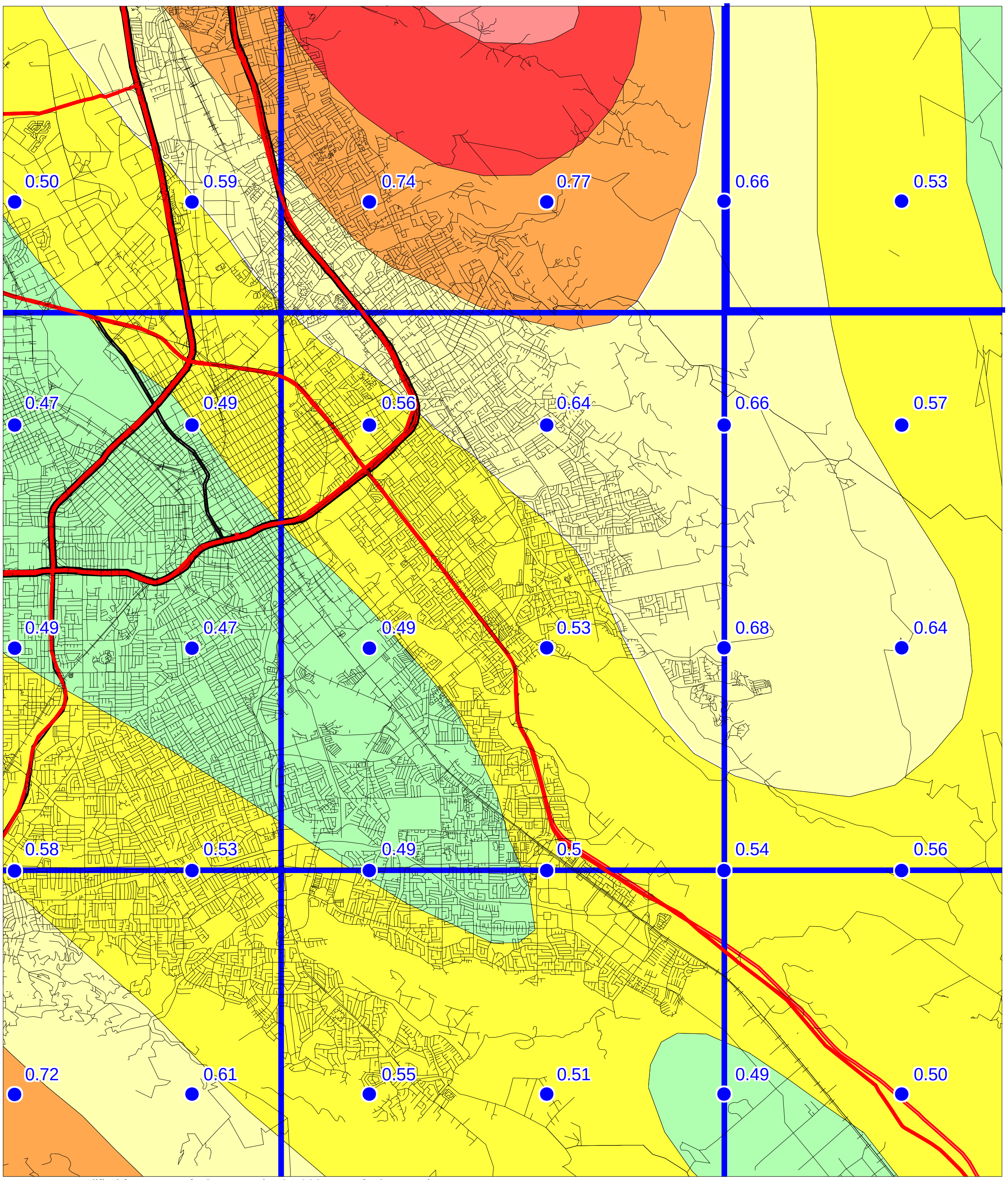
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

SAN JOSE EAST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3
Miles

Department of Conservation
Division of Mines and Geology

Figure 3.1

SAN JOSE EAST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS

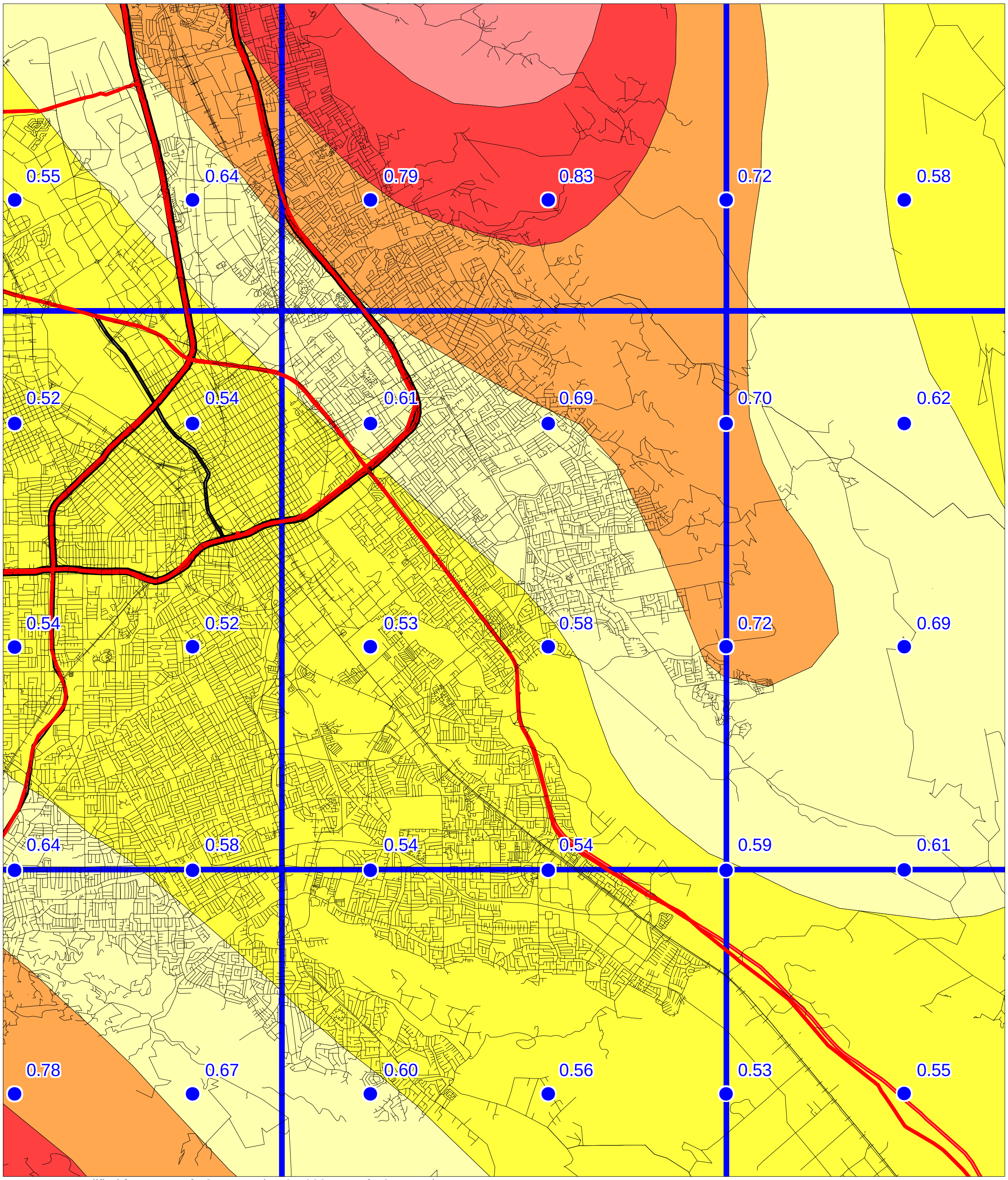


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Figure 3.2

SAN JOSE EAST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS

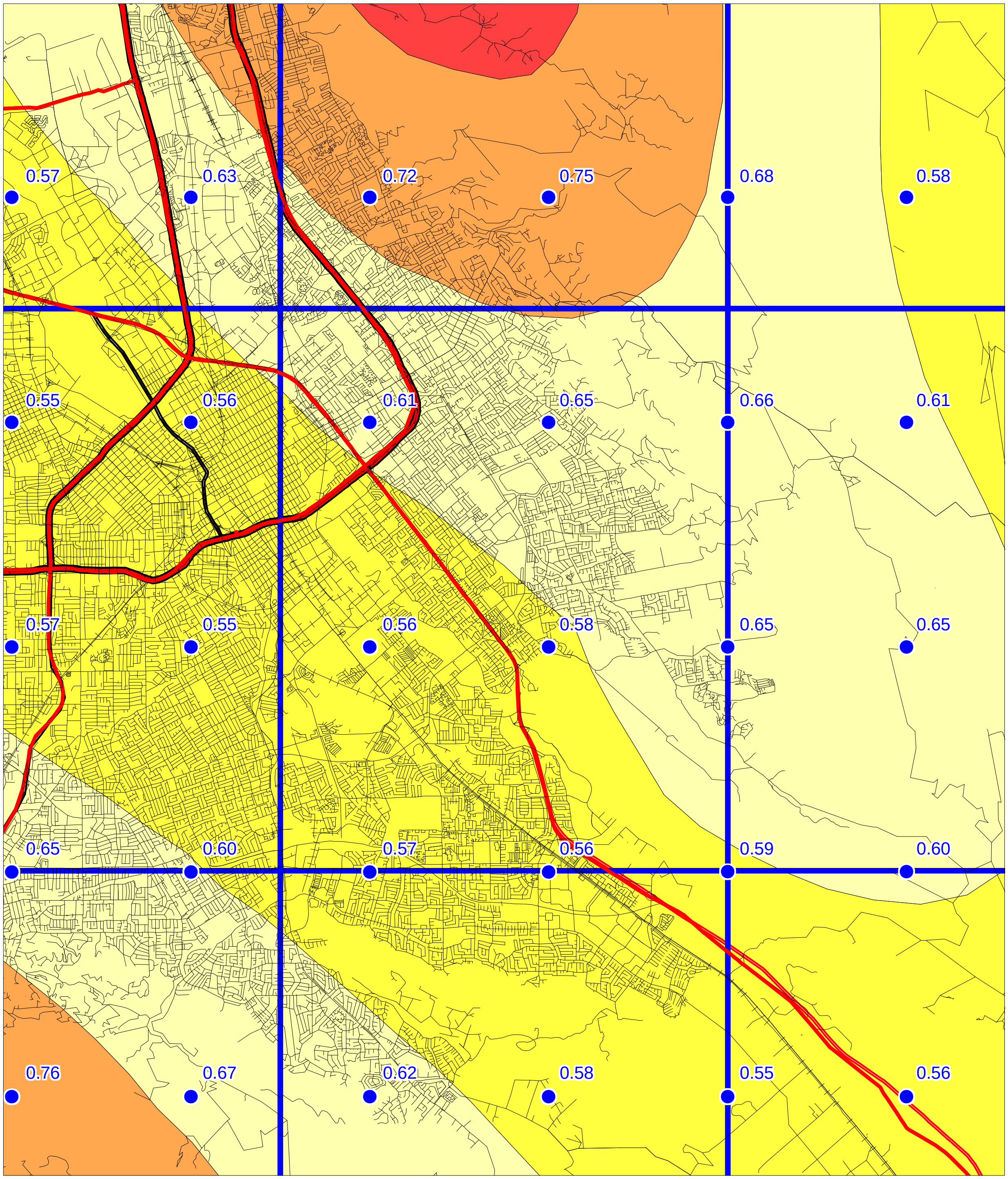

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Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

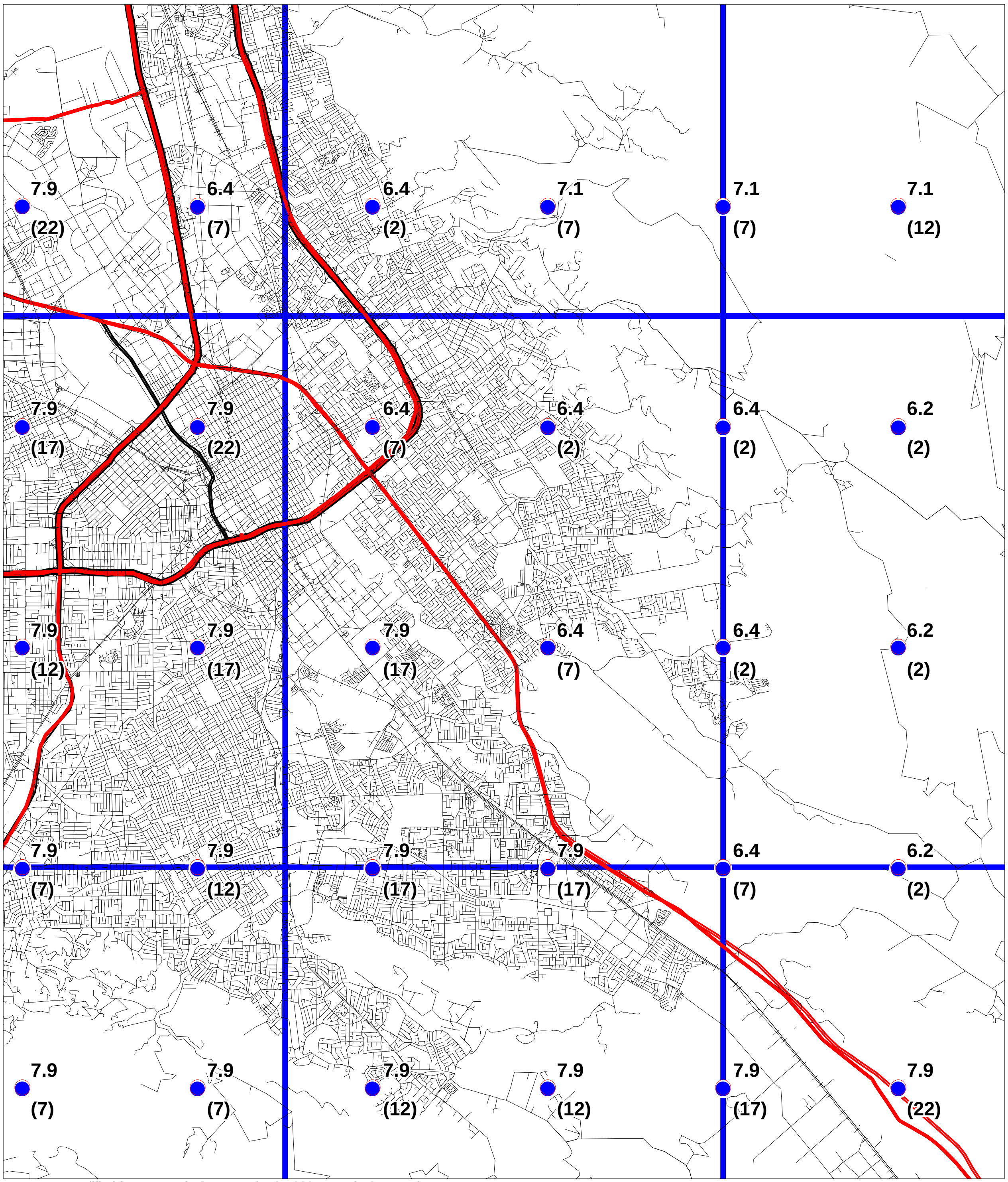
1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation

SAN JOSE EAST 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 1.5 3
Miles

Department of Conservation
Division of Mines and Geology

Figure 3.4

of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

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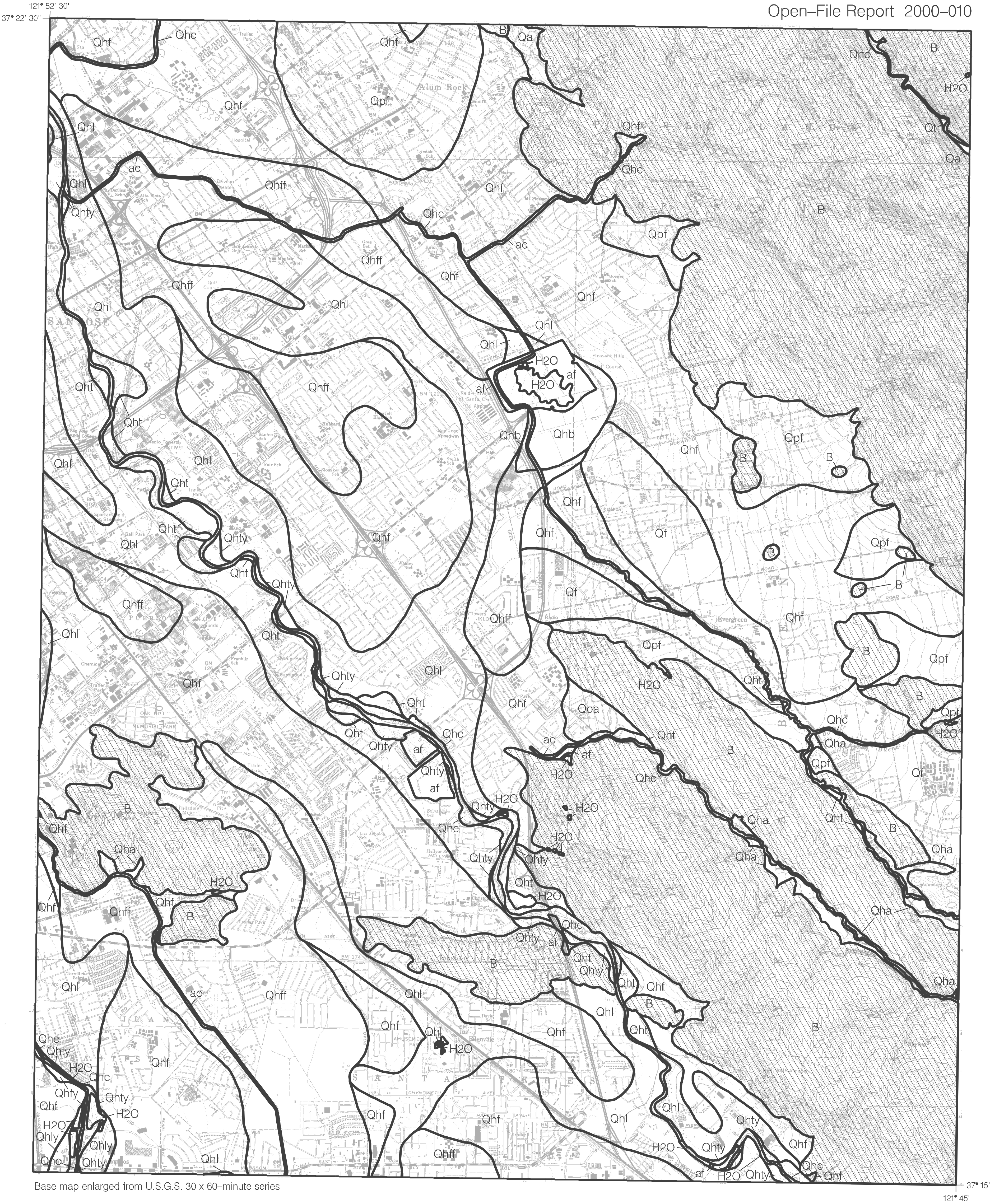


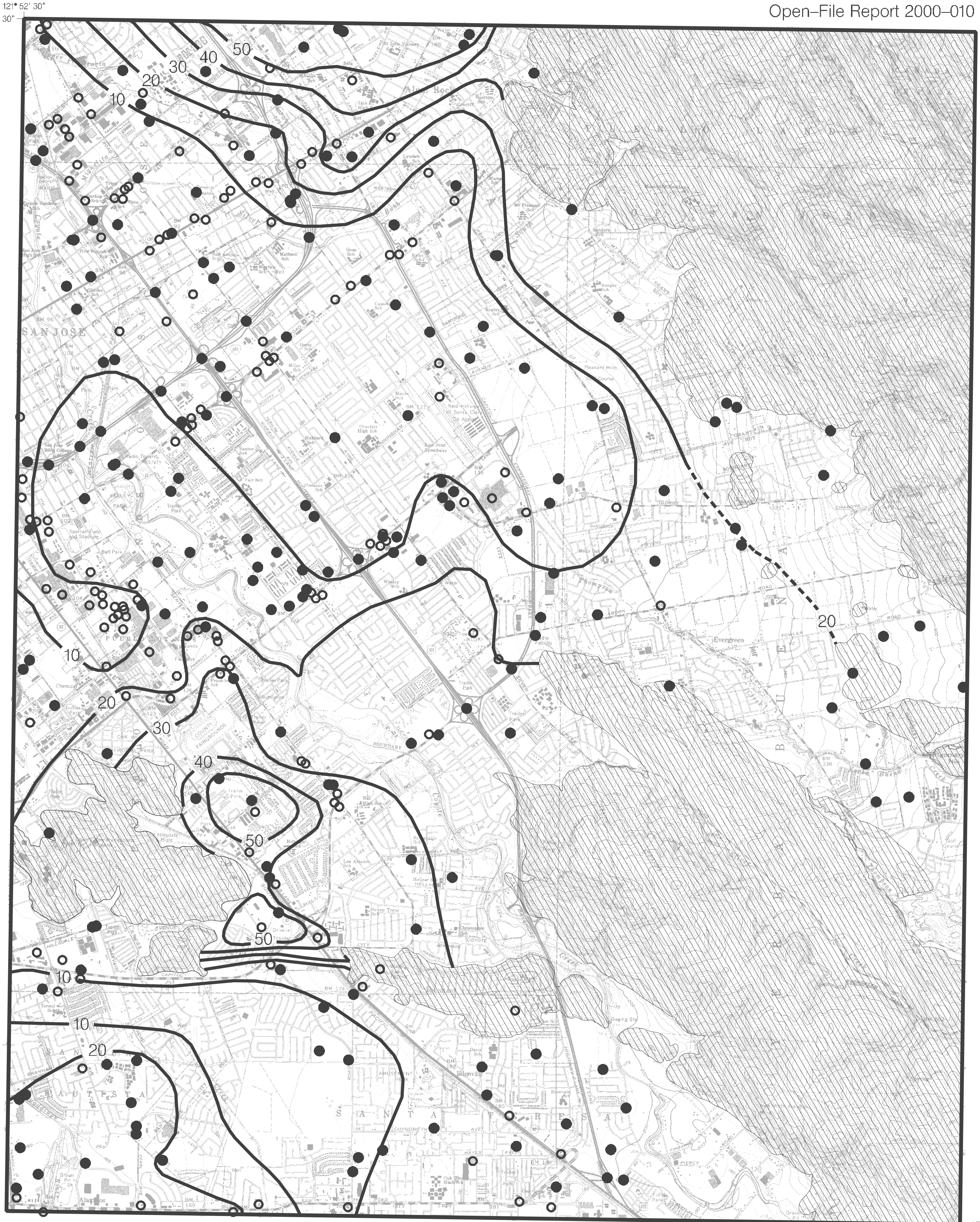
Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1. Quaternary geologic map of the San Jose East Quadrangle, California. See text for explanation of units. *Modified from Knudsen and others (2000).*

Pre–Quaternary bedrock

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.2. Depth to historically high groundwater, and locations of boreholes used in this study, San Jose East Quadrangle.

10 — Depth to ground water, in feet; contours are dashed where there is greater uncertainty

Geotechnical borings used in liquefaction evaluation

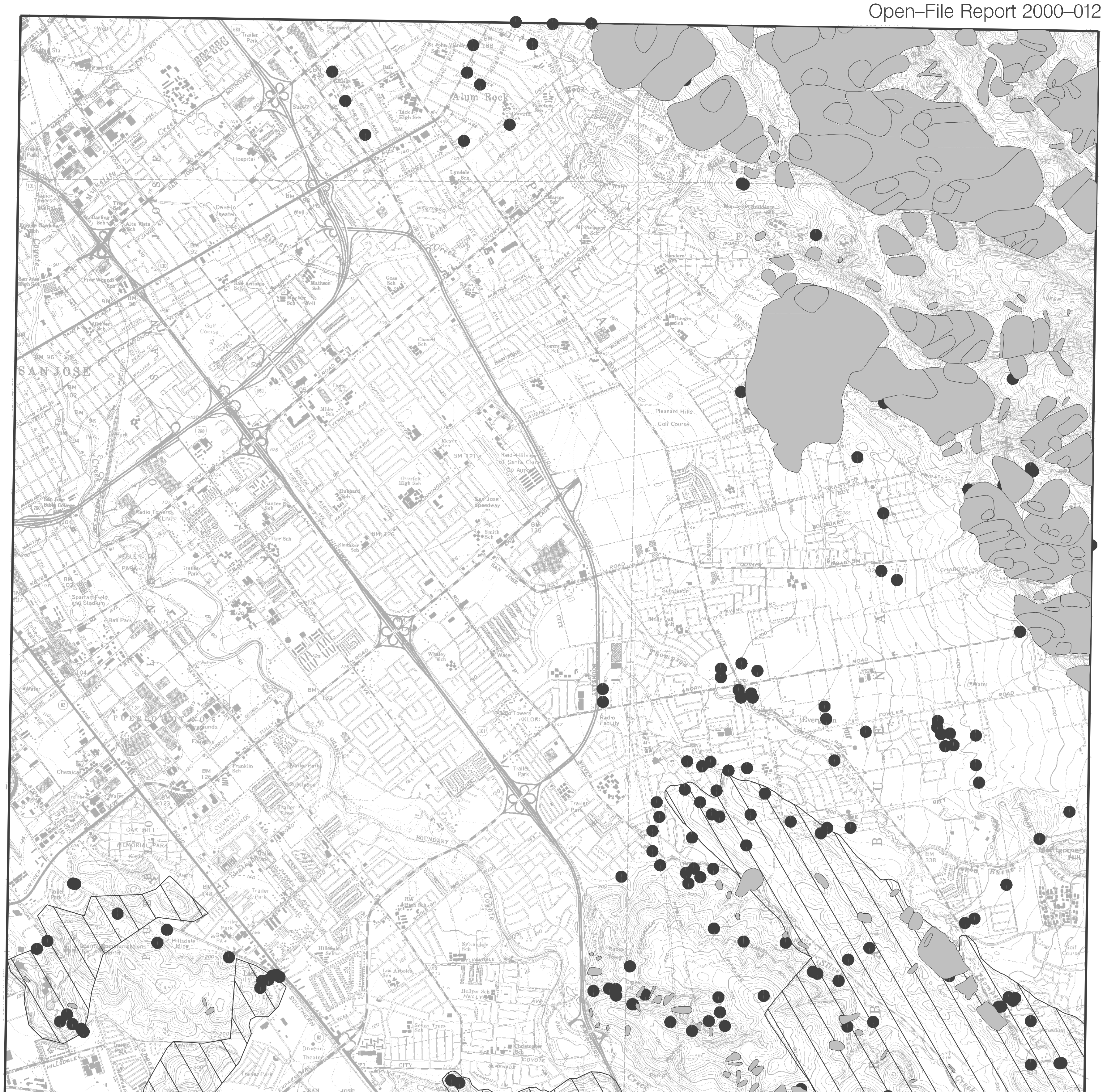
Bedrock

Water level data provided by the Santa Clara Valley Water District

ONE MILE

SCALE

N



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, San Jose East Quadrangle.

● shear test sample location — landslide — areas of significant grading

ONE MILE

SCALE